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in the Pinaleno Mountains:
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Squirrel Study Committee

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Assessment of the Effects of Exotic Spruce Aphid and Other Insects to Engelmann Spruce in the Pinaleño Mountains

A Final Report for The Mt. Graham Red Squirrel Study Committee

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Spruce aphid (*Elatobium abietinum* (Walker) (Homoptera: Aphididae)) is an exotic insect newly introduced to the Pinaleños. . It is incurring outbreaks in both the Pinaleños and the White Mountains under conditions that exceed it's known biological limits, and is likely to persist in the environment, with recurring epizootic events and significant ecosystem effects. Concurrently, outbreaks of native bark beetles, particularly spruce beetle and western balsam bark beetle (*Dendroctonus rufipennis* (Kirby) and *Dryocoetes confusus* Swaine, respectively (Coleoptera: Scolytidae)), as well as a recently terminated outbreak of the native defoliator *Nepytia janetae* (Lepidoptera: Geometridae) are dramatically altering the nature of the highest elevation squirrel habitat on the mountain range, spruce-fir. This study was initiated in order to determine what effects these insects will have on Mount Graham red squirrel habitat, especially on the distribution and abundance of red squirrel food resources.

In the near future, the native insect species will have greater effects in the spruce-fir type than will spruce aphid, causing high levels of mortality in both Engelmann spruce and corkbark fir, particularly in pole-sized and mature trees. Spruce aphid will cause high levels of mortality to Engelmann spruce seedlings and saplings, as well as any larger trees not killed by bark beetles. In the longer term, spruce aphid may prevent Engelmann spruce from regenerating abundantly in any of the vegetation types on the mountain. In my opinion, that is the most likely scenario. However, it is premature at this point to be more definite. Analysis of the Pinaleño and White Mountains temperature data will hopefully indicate how often defoliation episodes are likely to occur, and therefore allow us to project tree survivorship.

PROGRESS & RESULTS ON SPECIFIC STUDY OBJECTIVES

Four objectives were established in the Proposal, addressing squirrel food

resource effects (tree defoliation and mortality, and projected effects to specific foods), weather patterns associated with Southwestern aphid epizootics, bark beetle and *N. janetae* impacts to tree populations, and life history of spruce aphid (which is unknown). Progress made to date on each study objective is given below.

Obj. 1: Assess the near-term effects of spruce aphid to the distribution and abundance of food resources by a) evaluating defoliation and mortality to Engelmann spruce and corkbark fir, b) assessing observed and presumptive effects to seed and cone production and to fungal fruiting body production.

Thirty plots were measured on a grid pattern above 8500 ft (Fig. 1), including 25 temporary plots 9 permanent plots, and 9 plots centered on squirrel middens paired to nearby non-midden plots. Engelmann spruce density (trees 20 cm or larger) on these plots ranged from 32 to 795 trees per ha. Total tree density ranged from 350 to 890 trees per ha. Other tree species included corkbark fir, Douglas-fir, ponderosa pine, Rocky mountain maple, southwestern white pine, white fir, and willow.

The 2000 measurements indicate that Engelmann spruce trees were severely defoliated in two-thirds of the host type, including trees in the mixed-conifer, transition, and spruce-fir types (Fig. 1, Table 1).

Table 1. Mean Defoliation Index (DI) by plot, trees 20 cm and larger in diameter.

Point	Mean DI
9	9.0
11	3.0
16	6.3
17	9.0
19	6.3
20	1.7
22	8.5
24	9.0
25	4.9
26	9.0
27	7.6
28	1.7
29	1.7
30	0.0
31	0.0
36	0.0
37	0.0
41	2.3
42	0.0
43	0.0
47	0.0
48	0.0
49	8.0
51	1.0
52	0.0
57	0.0
60	0.0
09M	8.0
16M	6.2
24M	7.0
25M	7.8
27M	3.0
36M	0.1
48M	0.0
60M	0.0

Little or no defoliation occurred on plots on, near, or east of the ridge that runs from Mt. Graham down towards Shannon Park, even though aphids have been found there.

This indicates that either a) aphids did not disperse from the original establishment area near Highwater Cienega to the east side of the mountain range with enough time for populations to increase and cause defoliation, or b) conditions on the east side of the mountain range are less favorable for aphid populations.

On an individual tree basis, the 1999/2000 event in the Pinalenos was extensive, and the most severe seen to date in the Southwest. North and west of the Mt. Graham-Shannon Park ridge, 60% of the plots had severe mean defoliation indices (DI 8 or higher) (Table 1). Results from the White Mountain indicate that 25-40% of trees with DI of 8 or higher will die within three years. I have conducted several site visits to the Pinalenos since these plots were established, and I believe that mortality already exceeds that seen in the White Mountains. Spruce beetle will cause additional mortality in the mature trees.

Midden plots have not been comparatively analyzed, but superficially they appear neither more nor less defoliated than non-midden plots. Species composition for midden plots was very similar to their nearby non-midden plots.

It does not take sophisticated research to conclude that these levels of defoliation and mortality, especially on a recurring basis, combined with spruce beetle-related mortality, will greatly reduce seed and cone production. Combined impacts from the aphid and bark beetles have already devastated the spruce-fir vegetation type. In the near term, the spruce beetle and western balsam bark beetle outbreaks are a natural catastrophic disturbance event, perhaps creating conditions similar to those that preceded establishment of the existing forest. Spruce aphid is impacting smaller spruce and regeneration, in addition to the mature spruce (many of which would die from spruce beetle in any case). Impacts from spruce aphid are more extensive and severe than expected, such that questions regarding fungal fruiting body production associated with declining and dead trees in patches are

basically moot points – mortality and loss of regeneration capacity are overriding

factors.

2. Determine if spruce aphid population epizootics in the Southwest are associated with specific weather phenomenon, especially winter temperature regimes, and evaluate the historic frequency of those phenomena. Temperature data loggers were placed on Emerald Peak, the telescope site, and Heliograph Peak, and will be read in May or June. Temperature data has been supplied by the Study Committee for two additional sites. This data will be used to evaluate the likelihood that the topographic, temperature, and defoliation patterns are related. Longer term Study Committee data and data from the RAWs station at Columbine will be used in conjunction with temperature and general defoliation records from the White Mountains to identify any relationships between defoliation episodes and seasonal weather patterns. More specifically, the data will be examined to determine if long, warm autumns, autumns without severe cold events, mean ambient monthly temperatures, minimum monthly temperatures, and frequency/magnitude of warm days are associated with defoliation events.
3. Assess the likely effects of spruce aphid, bark beetles, and *N. janetae* impacts to forest tree population dynamics, especially with respect to forest structure, species composition, and related habitat requirements of the Mount Graham red squirrel. Analyses have not been completed, but habitats have already been sufficiently altered that most, if not all, squirrels have abandoned the spruce-fir type. To date, this is primarily caused by tree mortality from bark beetles and *N. janetae*.

This objective is basically a long-term modeling objective, in which the data collected as part of this study and concurrent research in the White Mountains will be used to project long-term vegetation dynamics. A regeneration model for mixed-conifer species in the Southwest is currently under review, and is necessary to complete this objective. I am confident that, with that model, it will be possible to project the length of time to re-establish cone-bearing forest vegetation, as well as probable species composition at various time points for the spruce-fir vegetation type. Likewise, the dynamics of the future forest in the mixed-conifer Individual seedlings collected in 2000 have not yet been examined in the laboratory for age estimates. Efforts to obtain funding (from other sources) for conducting a more thorough regeneration survey (specifically, to determine the number of years for seedlings to attain 4.5 ft, as well as to evaluate the adequacy of Engelmann spruce and corkbark fir regeneration), as well as conducting studies to determine the cumulative effects of forest insects on fuels conditions in high elevation forests, have not been successful.

Concerns that corkbark fir will also be a susceptible host specie have been somewhat alleviated. Several different instars of spruce aphid were observed feeding on both corkbark fir and Douglas-fir in early winter. Defoliation was

insignificant, indicating that those species are either inadequate as a food resource, or are not suitable for most of the autumn, when aphid populations are high. Also, aphid-related mortality has not been observed in the White Mountains in either corkbar fir or Douglas-fir.

4. Monitor insect populations in order to obtain some understanding of their seasonal life histories in the Pinales.

Since August, insects have been collected from 20 trees every 3 to 5 weeks in order to monitor population density, life stage, and defoliation. So far, all life stages of the aphid's complete life cycle have been observed. The egg stage, though observed, has not been confirmed as no aphids have (yet) eclosed from those eggs. Confirmation of the complete life cycle, as opposed to the anholocyclic (mostly parthenogenic) life cycle seen in maritime climates is fundamental to evaluating the likely persistence and severity of this pest in the Sky Islands and other Southwestern forests. A life cycle with a more cold-hardy overwintering stage explains in part how this insect survives conditions far colder than the literature and experience elsewhere indicate that it can survive, let alone exhibit epizootics.

Collected insects have not yet been measured to identify stadium, or counted, both of which are necessary to develop preliminary life tables.

UPCOMING WORK

Permanent plots will be remeasured this summer in order to evaluate tree mortality. Additional plots will be measured in the mixed-conifer type, as the selected plot size was too small to capture sufficient Engelmann spruce in that type. Using funding from another source, a fuels inventory in aphid-impacted and Douglas-fir tussock moth areas will be conducted. Life history, insect density, and defoliation will continue to be monito

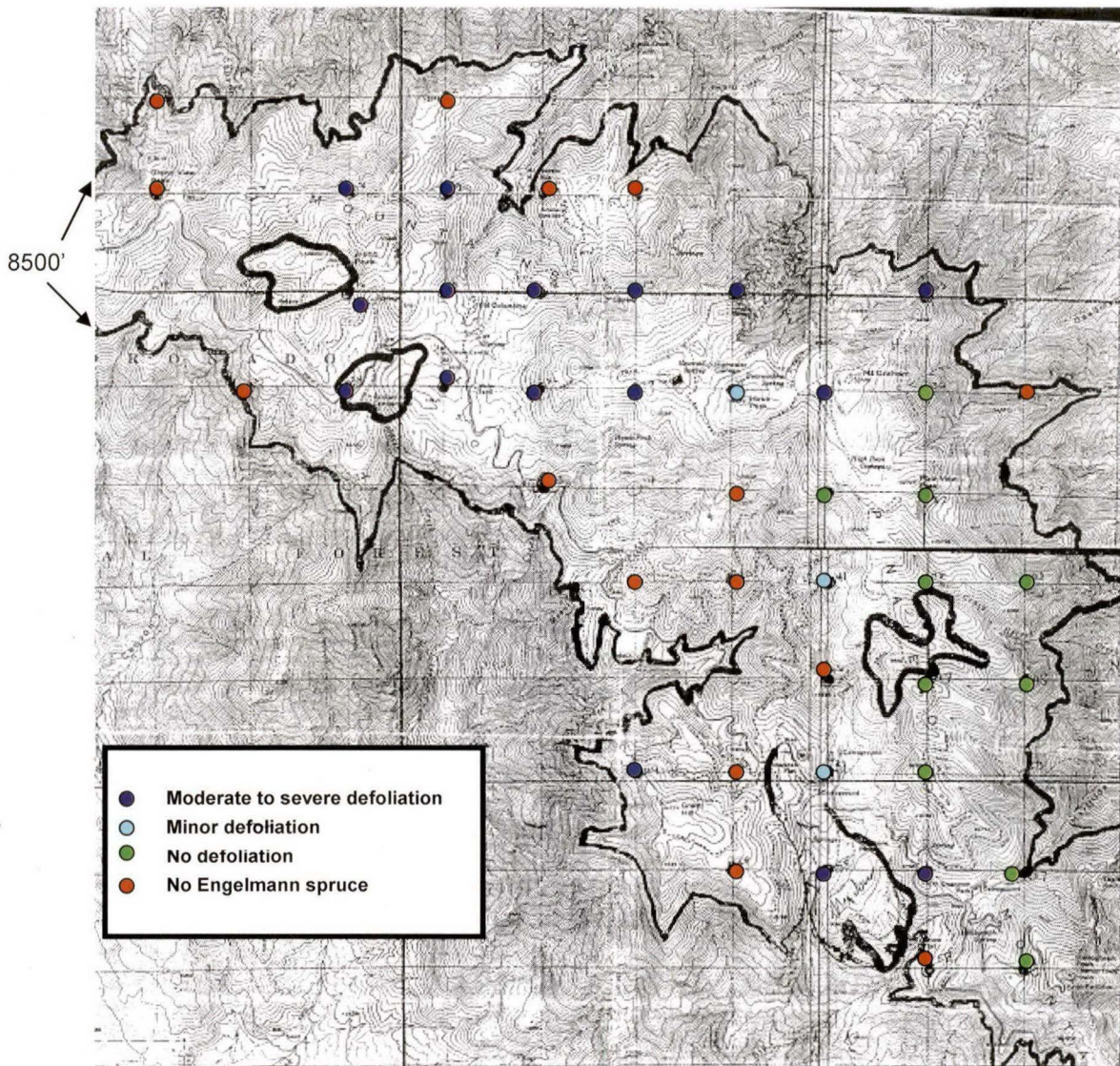


Figure 1. Severity of defoliation from spruce aphid for plots assessed in 2000.

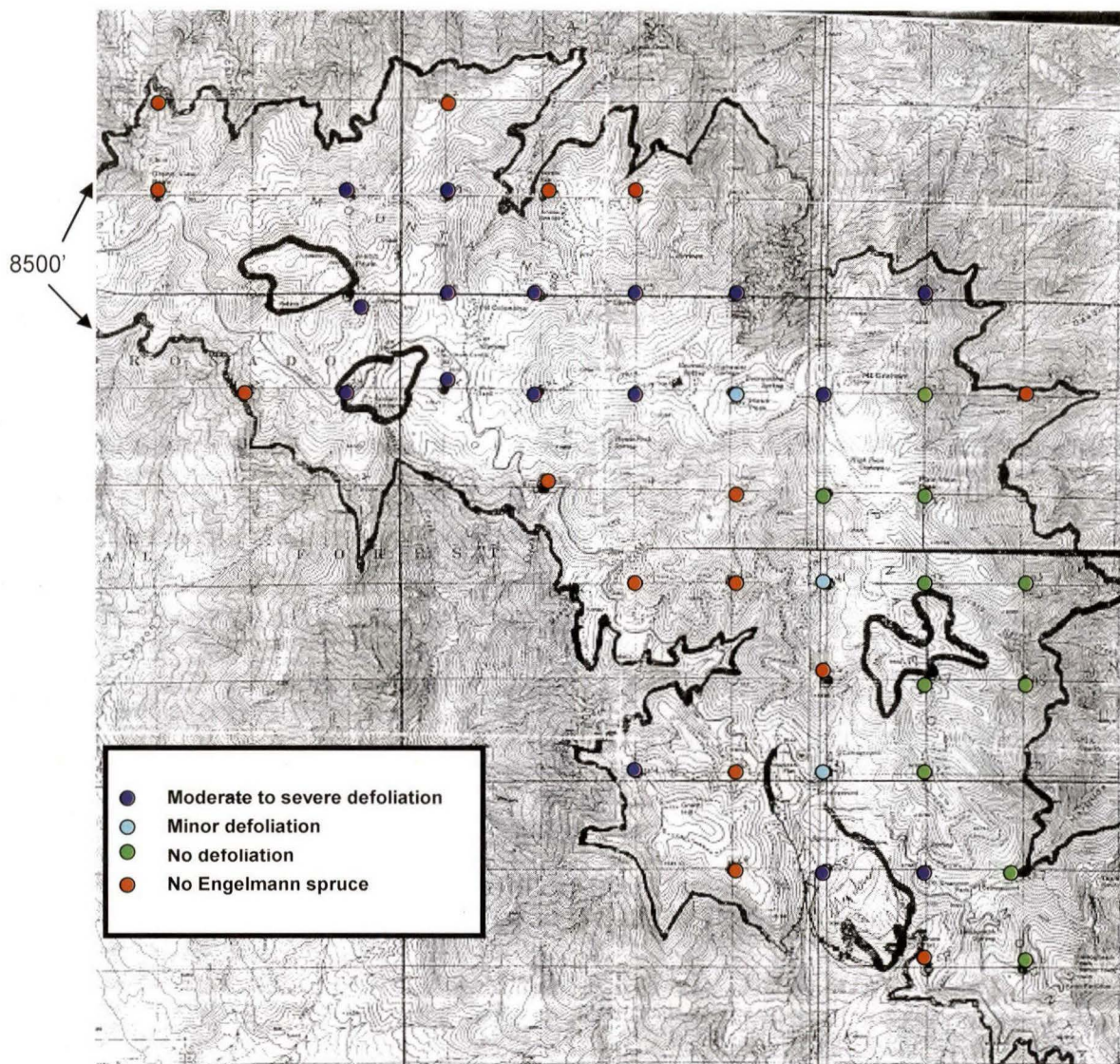


Figure 2. Highest level of defoliation from spruce aphid observed on each permanent plot, 2000-2002.